HOLLOW FIBER FABRICS

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of US Provisional Application No. 60/438,350, filed January 7, 2003.

FIELD OF THE INVENTION

The present invention relates to fibrous fabrics containing hollow fibers and processes of making hollow fibers.

BACKGROUND OF THE INVENTION

Commercial woven and nonwoven fabrics are typically comprised of synthetic polymers formed into fibers. These fabrics are typically produced with solid fibers that have a high inherent overall density, typically 0.9g/cm^3 to 1.4g/cm^3. The overall weight or basis weight of the fabric is often dictated by a desired opacity of the fabric to promote an acceptable thickness, strength and protection perception.

One reason for the increased usage of polyolefinic polymers (polypropylene and polyethylene) is that their bulk density is significantly lower than polyester, polyamide and regenerated cellulose fiber. The polypropylene density is around 0.9g/cm^3, while the regenerated cellulose and polyester density values can be higher than 1.35g/cm^3. The lower bulk density means that at equivalent basis weight and fiber diameter, more fibers are available to promote a thickness, strength and protection perception for the lower density polypropylene. Many of these attributes can be correlated with opacity. Therefore, manipulating the inherent opacity of the fiber and fabric in a consumer product can lead to better overall user acceptability.

A great deal of effort has been spent to address improve consumer acceptance by increasing the opacity of a fabric by reducing the overall fiber diameter. In woven fabrics, the spread of "microfiber" technology for improved softness and strength has become fashionable. In nonwoven fabrics, the use of "micro" fiber spunbond and meltblown technologies has allowed improvements in opacity by reducing the fiber diameter.

The present invention has found that using hollow fibers provides substantial improvements in opacity at equivalent outer fiber diameter and basis weight, through a reduction in overall bulk density of the fiber.

SUMMARY OF THE INVENTION

The present invention is directed to fibrous fabric comprising hollow fibers. Preferably, the fibrous fabrics will have an opacity greater than a fibrous fabric with an equivalent basis weight and made with the same material and the same fiber diameter. The fibrous fabric comprising hollow fibers may also have an opacity greater than a higher basis weight fibrous fabric containing the same material and having an equivalent fiber diameter and the same number of fibers. The perimeter of the hollow region of the hollow fibers is substantially non-concentric to the outer perimeter of the hollow polymeric fibers. The hollow fibers can be monocomponent and multicomponent, as well as monoconstituent or multiconstituent. These hollow fibers are then consolidated into woven and nonwoven fabrics that are then converted into articles.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawing where:

Figure 1 illustrates a hollow fiber of the present invention.

Figure 2 illustrates a concentric hollow fiber.

Figures 3, 4, 5, and 6 illustrate several variations of non-concentric hollow fiber of the present invention.

Figure 7 is a photograph of a non-concentric hollow fiber of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

All percentages, ratios and proportions used herein are by weight percent of the composition, unless otherwise specified. Examples in the present application are listed in parts of the total composition.

The specification contains a detailed description of (1) materials of the present invention, (2) configuration of the fibers, (3) material properties of the fibers, (4) processes, and (5) articles.

(1) Materials

Thermoplastic polymeric and non-thermoplastic polymeric materials may be used in the present invention. The thermoplastic polymeric material must have rheological characteristics suitable for melt spinning. The molecular weight of the polymer must be sufficiently high to enable entanglement between polymer molecules and yet low enough to be melt spinnable. For melt spinning, thermoplastic polymers having molecular weights below 1,000,000 g/mol, preferably from about 5,000 g/mol to about 750,000 g/mol, more preferable from about 10,000 g/mol to about 500,000 g/mol and most preferably from about 50,000 g/mol to about 400,000 g/mol.

The thermoplastic polymeric materials must be able to solidify fairly rapidly, preferably under extensional flow, and form a thermally stable fiber structure, as typically encountered in known processes such as a spin draw process for staple fibers or a spunbond continuous filament process. Preferred polymeric materials include, but are not limited to, polypropylene, polyethylene, polyester, polyamide, polyimide, polylactic acid, polyhydroxyalkanoate, polyvinyl alcohol, ethylene vinyl alcohol, polyacrylates, and copolymers thereof and mixtures thereof. Other suitable polymeric materials include ethylene acrylic acid, polyolefin carboxylic acid copolymers, and combinations thereof.

The hollow fibers of the present invention may be comprised of a non-thermoplastic polymeric material. Examples of non-thermoplastic polymeric materials include, but are not limited to, viscose rayon, lyocell, cotton, wood pulp, regenerated cellulose, and mixtures thereof. The non-thermoplastic polymeric material may be produced via solution or solvent spinning. The regenerated cellulose is produced by extrusion through capillaries into an acid coagulation bath.

Depending upon the specific polymer used, the process, and the final use of the fiber, more than one polymer may be desired. The polymers of the present invention are present in an amount to improve the mechanical properties of the fiber, improve the processability of the melt, and improve attenuation of the fiber. The selection of the polymer and amount of polymer will also determine if the fiber is thermally bondable and affect the softness and texture of the final product.

Optionally, other ingredients may be incorporated into the spinnable composition. The optional materials may be used to modify the processability and/or to modify physical properties such as opacity, elasticity, tensile strength, wet strength, and modulus of the final product. Other benefits include, but are not limited to, stability including oxidative stability, brightness, color, flexibility, resiliency, workability, processing aids, viscosity modifiers, and

odor control. Examples of optional materials include titanium dioxide, calcium carbonate, colored pigments, and combinations thereof. Further additives including inorganic fillers such as the oxides of magnesium, aluminum, silicon, and titanium may be added as inexpensive fillers or processing aides. Other inorganic materials include hydrous magnesium silicate, titanium dioxide, calcium carbonate, clay, chalk, boron nitride, limestone, diatomaceous earth, mica glass quartz, and ceramics. Additionally, inorganic salts, including alkali metal salts, alkaline earth metal salts, phosphate salts, may be used.

(2) Configuration

The hollow fibers of the present invention will have a hollow region. Figure 1 illustrates a hollow fiber 10. The hollow region 20 has a perimeter 22. The solid region 30 of the hollow fiber 10 surrounds the hollow region 20. The perimeter of the hollow region 22 is also the inside perimeter of the solid region. The outside perimeter 32 of the solid region 30 is also the outside perimeter of the hollow fiber 10. The circumscribed diameter of the hollow fiber may also be the outside perimeter 32.

The hollow region is defined as the part of the fiber that does not contain the fiber material. It may also be described as the void area, void volume, or empty space. The hollow region may be filled with air or possibly a liquid. The hollow region will comprise from about 2% to about 60% of the fiber. Preferably, the hollow region will comprise from about 5% to about 40% of the fiber. More preferably, the hollow region comprises from about 5% to about 30% of the fiber and most preferably from about 10% to about 30% of the fiber. The percentages are given for a cross sectional region of the hollow fiber (i.e. two dimensional). If described in three-dimensional terms, the percent void volume of the fiber will be equivalent to the percent of hollow region.

The percent of hollow region must be controlled for the present invention. The percent hollow is preferably not below 2% or the benefit of the hollow region is not significant. However, the hollow region must not be greater than 60% or the fiber may collapse. The desired percent hollow depends upon the materials used, the end use of the fiber, and other fiber characteristics and uses.

The fiber "diameter" of the hollow fiber of the present invention is defined as the circumscribed diameter of the outer perimeter 32 of the hollow fiber. The diameter is not of the hollow region. Preferably, the hollow fiber will have a diameter of less than 100 micrometers. More preferably the fiber diameter will be from about 10 micrometers to about 100 micrometers and preferably from about 10 micrometer to about 50 micrometers. Fiber

diameter is controlled by spinning speed, mass throughput, temperature, spinneret geometry, and blend composition, among other things.

Preferably, the hollow region of the hollow fibers will be of a particular shape. The perimeter or outside edge of the cross section of the hollow region will be substantially non-concentric to the outer perimeter or outer edge of the solid region or hollow fiber. As used herein, the term "non-concentric" is used to mean not having the same center point and/or not having the same shape or curvature (i.e. slope differential). Therefore, a hollow fiber is defined as being non-concentric if either the center point of the hollow region is not the same as the center point of the hollow fiber or if the perimeter of the hollow region is not the same shape or curvature as the outside perimeter of the hollow fiber. Most preferably, the shape of the hollow region is substantially non-circular. For example, the hollow region may be triangular or square in shape. The triangular or square shape will typically have rounded edges.

Without being bound by theory, it is believed that the hollow core allows for increased benefits in optical characteristics which increase opacity. The increase in opacity of the fibrous fabric may be due to changes in at least one light characteristic selected from the group consisting of reflection, refraction, diffraction, absorption, scattering, and combinations thereof. This increase in opacity may be even greater when the fibers are non-concentric hollow fibers versus solid fibers or concentric hollow fibers.

Figure 2 is used to illustrate what is a concentric hollow fiber and not a "non-concentric" hollow fiber. As shown, the center of the hollow region and the center of the hollow fiber are the same. Additionally, the shape or curvature of the perimeter of the hollow region and the hollow fiber are the same. Figure 3 illustrates non-concentric hollow fibers having several different shapes of the hollow region. These non-concentric hollow fibers are illustrative of not having the same curvature or shape in the hollow region as compared to the hollow fiber. As shown, these shapes may have straight or curved edges. Additionally, part of the perimeter of the hollow region may have the same curvature as the hollow fiber as long as the entire curvature is not the same. The hollow regions may or may not have the same center point as the hollow fiber. Figure 4 illustrates that the shape of the hollow fiber need not be circular.

Figure 5 illustrates other non-concentric hollow fibers where the hollow region does not have the same center point as the hollow fiber. The perimeter of the hollow region and the outer perimeter of the hollow fiber may be of the same curvature. Figure 6 illustrates non-concentric hollow fiber having a variety of shapes for the hollow region. The hollow

region may contain one or more regions. Figure 7 is a photograph showing a non-circular, partially square shaped, hollow region.

The mono and multiconstituent hollow fibers of the present invention may be in many different configurations. Constituent, as used herein, is defined as meaning the chemical species of matter or the material. Fibers may be of monocomponent or multicomponent in configuration. Component, as used herein, is defined as a separate part of the fiber that has a spatial relationship to another part of the fiber.

The hollow fibers of the present invention may be multicomponent hollow fibers. Multicomponent fibers, commonly a bicomponent fiber, may be in a side-by-side, sheath-core, segmented pie, ribbon, or islands-in-the-sea configuration. The sheath may be non-continuous or continuous around the core. The hollow fibers of the present invention may have different geometries that include round, elliptical, star shaped, rectangular, multi-lobal, and other various eccentricities. The hollow regions in the fibers may be singular in number or multiple. The holes may also be produced by dissolving out a water-soluble component, such as PVOH, EVOH and starch, for non-limiting examples.

(3) Material Properties

The fibrous fabrics of the present invention will have a basis weight and opacity that can be measured. Opacity can be measured using TAPPI Test Method T 425 om-01 "Opacity of Paper (15/d geometry, Illuminant A/2 degrees, 89% Reflectance Backing and Paper Backing)". The opacity is measured as a percentage. The opacity of the fibrous fabric containing hollow fibers will be several percentage points of opacity greater than the fibrous fabric containing solid fibers. The opacity may be from about 2 to about 50 percentage points greater and commonly from about 4 to about 30 percentage points greater.

Basis weight is the mass per unit area of the substrate. Independent measurements of the mass and area of a specimen substrate are taken and calculation of the ratio of mass per unit area is made. Preferably, the basis weight of the fibrous fabrics of the present invention will be from about 4 grams per square meter (gsm) to about 70 gsm depending upon the use of the fabric.

Additionally, the fibrous fabrics produced from the hollow fibers will also exhibit certain mechanical properties, particularly, strength, flexibility, elasticity, extensibility, softness, thickness, and absorbency. Measures of strength include dry and/or wet tensile strength. Flexibility is related to stiffness and can attribute to softness. Softness is generally described as a physiologically perceived attribute that is related to both flexibility and

texture. Absorbency relates to the products' ability to take up fluids as well as the capacity to retain them.

(4) Processes

The first step in producing a fiber is the compounding or mixing step. In the compounding step, the raw materials are heated, typically under shear. The shearing in the presence of heat will result in a homogeneous melt with proper selection of the composition. The melt is then placed in an extruder where the material is mixed and conveyed through capillaries and fibers are formed. A collection of fibers is combined together using heat, pressure, chemical binder, mechanical entanglement, hydraulic entanglement, and combinations thereof resulting in the formation of a nonwoven web or fabric. The nonwoven is then assembled into an article. Alternatively, the fibers can be consolidated together in a textile process to produce a woven web.

Equipment

The equipment used to produce the fibers in the examples came from one of three different types of spinning equipment. The smallest is a four-hole bicomponent spinline made by Hills Inc. The second line has 82 holes and contains Hills Inc. bicomponent technology, modified from an original Alex James bicomponent spinline. The third line contains at least 144 holes (nominally 288) and is located at Hills Inc, with their bicomponent spinning technology. With these three small lines, fiber can either be collected via mechanical winding at low or high speed. These fibers can then be mechanically drawn to further decrease their diameter. Heat is frequently used in the drawing process. These fibers are then crimped, if desired, and cut to the desired length. These fibers are then converted into a fabric.

Although the exact equipment is not important for manifesting the invention of using hollow fiber in fabrics for better opacity, hollow fibers are typically produced using a special spinneret that divides the polymer melt stream as it exits the spin pack. In the case of the Hills Inc. spinneret technology, the melt stream is separated into four segments that converge after the exit of the spinneret. Other designs may make use of two or three segments that converge after exiting the spinneret. The size of the void can also be affected by pumping some low-pressure gas into the void. The exact process for producing the fiber is not critical to this invention.

Spinning

The present invention utilizes the process of melt spinning in its most preferred embodiment. In melt spinning, there is no mass loss in the extrudate. Solution spinning may be used for producing fibers from cellulose, cellulosic derivatives, starch, and protein.

Spinning will occur at 100°C to about 300°C. Fiber spinning speeds of greater than 100 meters/minute are required. Preferably, the fiber spinning speed is from about 500 to about 14,000 meters/minute. The spinning may involve direct spinning, using techniques such as spunlaid or meltblown, as long as the fibers are mostly non-continuous in nature. Continuous fibers are hereby defined as having length to width ratio greater than 5000. The fiber may also be produced using a spin and draw technique, where the fiber is spun at a relatively slow speed and mechanically drawn, with or without heat, to reduce the fiber diameter.

Multiconstituent blends or polymeric materials can be melt spun into fibers on conventional melt spinning equipment. The temperature for spinning ranges from about 100°C to about 300°C. The processing temperature is determined by the chemical nature, molecular weights and concentration of each component. The fibers spun can be collected using conventional godet winding systems or through air drag attenuation devices. If the godet system is used, the fibers can be further oriented through post extrusion drawing at temperatures from about 50 to about 200° C.

Multiconstituent blends may also be spun into fibers. For example, blends of polyethylene and polypropylene can be mixed and spun using this technique. Another example would be blends of polyesters with different viscosities or termonomer content. Multicomponent fibers can also be produced that contain differentiable chemical species in each component.

The fibers and fabrics made in the present invention often contain a finish applied after formation to improve performance or tactile properties. These finishes typically are hydrophilic or hydrophobic in nature and are used to improve the performance of articles containing the finish. For example, Goulston Technologies' Lurol 9519 can be used with polypropylene and polyester to impart a semi-durable hydrophilic finish.

(5) Articles

The hollow fibers may be converted to fabrics by different bonding methods. In a spunbond or meltblown process, the fibers are consolidated using industry standard spunbond type technologies while staple fibers can be formed into a web using industry standard carding, airlaid, or wetlaid technologies. Typical bonding methods include: calender (pressure and heat), thru-air heat, mechanical entanglement, hydraulic entanglement, needle

punching, and chemical bonding and/or resin bonding. Thermally bondable fibers are required for the pressurized heat and thru-air heat bonding methods. Fibers may also be woven together to form sheets of fabric. This bonding technique is a method of mechanical interlocking.

The hollow fibers of the present invention may also be bonded or combined with thermoplastic or non-thermoplastic fibers to make nonwoven articles. The thermoplastic polymeric fibers, typically synthetic fibers, or non-thermoplastic polymeric fibers, often natural fibers, may be blended together in the forming process or used in discrete layers. Suitable synthetic fibers include fibers made from polypropylene, polyethylene, polyester, polyacrylates, and copolymers thereof and mixtures thereof. Natural fibers include lyocell and cellulosic fibers and derivatives thereof. Suitable cellulosic fibers include those derived from any tree or vegetation, including hardwood fibers, softwood fibers, hemp, and cotton. Also included are fibers made from processed natural cellulosic resources such as rayon.

The hollow fibers of the present invention may be used to make nonwovens, among other suitable articles. Nonwoven or fibrous fabric articles are defined as articles that contains greater than 15% of a plurality of fibers that are non-continuous or continuous and physically and/or chemically attached to one another. The nonwoven may be combined with additional nonwovens or films to produce a layered product used either by itself or as a component in a complex combination of other materials, such as a baby diaper or feminine care pad. Preferred articles are disposable, nonwoven articles. The resultant products may find use in filters for air, oil and water; vacuum cleaner filters; furnace filters; face masks; coffee filters, tea or coffee bags; thermal insulation materials and sound insulation materials; nonwovens for one-time use sanitary products such as diapers, feminine pads, and incontinence articles; biodegradable textile fabrics for improved moisture absorption and softness of wear such as micro fiber or breathable fabrics; an electrostatically charged, structured web for collecting and removing dust; reinforcements and webs for hard grades of paper, such as wrapping paper, writing paper, newsprint, corrugated paper board, and webs for tissue grades of paper such as toilet paper, paper towel, napkins and facial tissue; medical uses such as surgical drapes, wound dressing, bandages, dermal patches and self-dissolving sutures; and dental uses such as dental floss and toothbrush bristles. The fibrous web may also include odor absorbents, termite repellants, insecticides, rodenticides, and the like, for specific uses. The resultant product absorbs water and oil and may find use in oil or water spill clean-up, or controlled water retention and release for agricultural or horticultural applications. The resultant fibers or fiber webs may also be incorporated into other materials

such as saw dust, wood pulp, plastics, and concrete, to form composite materials, which can be used as building materials such as walls, support beams, pressed boards, dry walls and backings, and ceiling tiles; other medical uses such as casts, splints, and tongue depressors; and in fireplace logs for decorative and/or burning purpose. Preferred articles of the present invention include disposable nonwovens for hygiene applications, such as facial cloths or cleansing cloths, and medical applications. Hygiene applications include wipes, such as baby wipes or feminine wipes; diapers, particularly the top sheet or back sheet; and feminine pads or products, particularly the top sheet. Other preferred applications are wipes or cloths for hard surface cleansing. The wipes may be wet or dry.

Staple Fiber Examples

The Examples below further illustrate the present invention. The crystalline PLA has an intrinsic viscosity of 0.97 dL/g with an optical rotation of –14.2. The amorphous PLA has an intrinsic viscosity of 1.09 dL/g with an optical rotation of –12.7. The poly(3-hydroxybutyrate co-alkanoate), PHA, has a molecular weight of 1,000,00g/mol before compounding. The polyhydroxybutyrate (PHB) was purchased from Goodfellow as BU 396010. The polyvinyl alcohol copolymer (PVOH) was purchased from Air Products Inc. and is a 2000 series polymer. One polypropylene was purchased from FINA as FINA 3860X. Three polypropylenes were purchased from Basell, Profax PH-835, Profax PDC-1298 and Profax PDC-1274. The polyethylene was purchased from Dow Chemical as Aspun 6811A. Five polyester resins were purchased from Eastman Chemical F61HC, 9663, 12822 as well as two copolyester resins 14285 and 20110.

Comparative Example 1: Fibrous web containing solid fibers. Dry measurements.

A polypropylene/Lyocell carded hydroentangled fabric was produced by blending 60wt% of Basell PH-835 staple fibers with 40wt% Lyocell. The Basell PH-835 fibers were spun, drawn and crimped to an average fiber diameter of 20μm. The Lyocell fiber is 1.5d, roughly 12μm in diameter. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
61.7	53.19
67.6	56.52
57.1	49.23
52.5	47.86

32.1	30.68
29.5	29.47

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen.

Comparative Example 2: Fibrous web containing solid fibers. Wet measurements.

A polypropylene/Lyocell carded hydroentangled fabric was produced by blending 60wt% of Basell PH-835 staple fibers with 40wt% Lyocell. The Basell PH-835 fibers were spun, drawn and crimped to an average fiber diameter of 30µm. The Lyocell fiber is 1.5d, roughly 12µm in diameter. The following nonwoven fabrics were produced and are measured wet after addition of 315wt% of water, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Dry Basis Weight (gsm)	**Opacity (%)**
61.8	41.0
63.8	41.8
65.9	41.4

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen.

Example 1: Fibrous web containing non-concentric hollow fibers. Dry measurements

A polypropylene/Lyocell carded hydroentangled fabric was produced by blending 60wt% of Basell PH-835 hollow staple fibers with 40wt% Lyocell. The percent void area of the Basell PH-835 hollow staple fibers is 20%. The Basell PH-835 fibers were spun, drawn and crimped to an average fiber diameter of 20µm. The Lyocell fiber is 1.5d, roughly 12µm in diameter. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
49.1	55.07
55.8	58.17
55.5	57.93
56.4	61.11
47.7	54.06
46.8	53.54
30.6	40.54
25.9	34.82

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen.

The increase in opacity as shown in this example versus Comparative Example 1 can be seen with this data. The following graph illustrates this difference.

Example 2: Fibrous web containing non-concentric hollow fibers. Wet measurements. A polypropylene/Lyocell carded hydroentangled fabric was produced by blending 60wt% of Basell PH-835 hollow staple fibers with 40wt% Lyocell. The Basell PH-835 fibers were spun, drawn and crimped to an average fiber diameter of 30μm. The percent void area of the Basell PH-835 hollow staple fibers is 15%. The Lyocell fiber is 1.5d, roughly 12μm in diameter. The following nonwoven fabrics were produced and are measured wet after addition of 315wt% of water, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Dry Basis Weight (gsm)	Opacity (%)
61.8	47.8
64.2	50.1
66.4	51.5

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen.

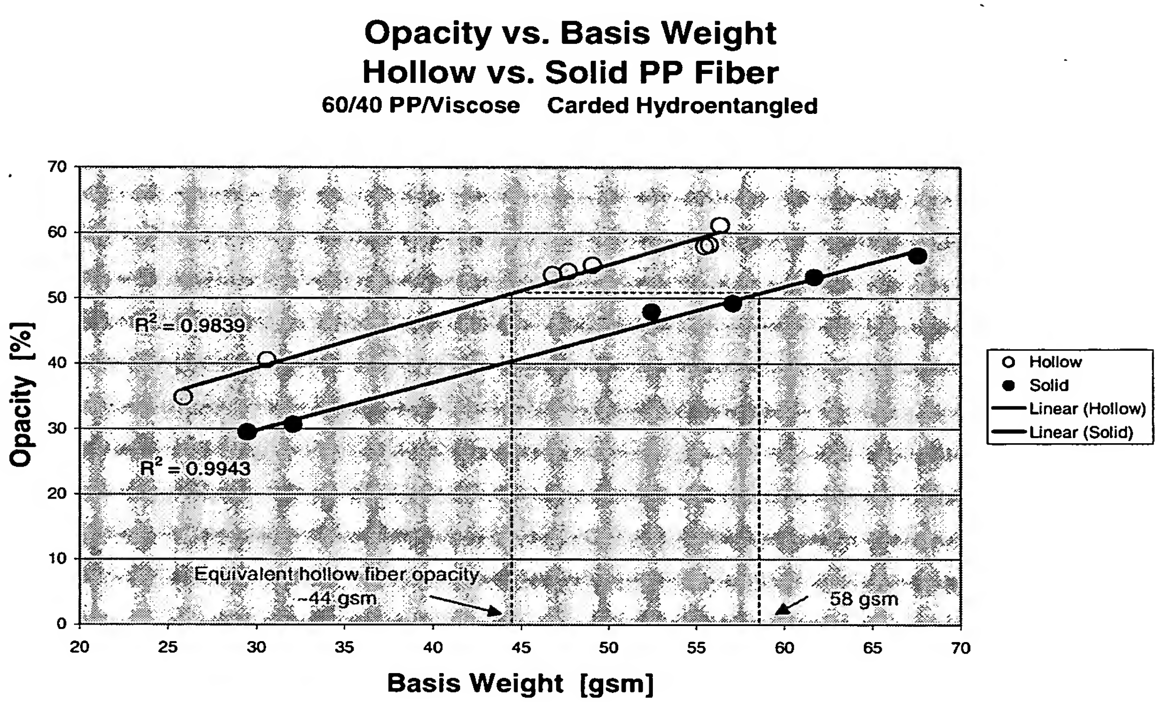
The increase in opacity as shown in this example versus Comparative Example 2 can be seen.

Example 3 - 22: The following table provides examples of fibers and fabrics composed of various polymers. Examples 3-11 illustrate single component fibers and Examples 12-22 illustrate bicomponent fibers. The bicomponent fibers typically have a sheath to core ratio of from about 20:80 to about 80:20. The fibers are produced either a direct spin process or spin and draw process. The table also provides the void volume of the hollow region. The void volumes ranges can be made depending on the mass through-put per hole and melt temperature. As the mass through-put increases and as the melt temperature decreases, the void volume generally increases. These fiber can be blended with other synthetic staple fibers or regenerated cellulose fibers.

Example Number	Polymer	Void volume
3	PLA - Biomer L9000	5-25%

4	Basell PDC-1274	5-30%
5	Basell PDC-1298	5-40%
6	Dow Aspun 6811A	5-20%
7	Eastman F61HC	5-20%
8	Eastman 9663	5-35%
9	Eastman 12822	5-40%
10	Eastman 14285	5-35%
11	Eastman 20110	5-25%
12	Sheath – Dow Aspun 6811A Core - Basell PH-835	5-25%
13	Sheath – Dow Aspun 6811A Core – Basell PDC-1274	5-35%
14	Sheath – Dow Aspun 6811A Core – Eastman F61HC	5-25%
15	Sheath – Basell PH-835 Core – Eastman F61HC	5-25%
16	Sheath – Eastman 20110 Core – Eastman F61HC	5-25%
17	Sheath – Dow Aspun 6811A Core – Eastman 9663	5-25%
18	Sheath – Eastman 14285 Core – Eastman F61HC	5-25%
19	Sheath – Eastman 14285 Core – Eastman 9663	5-30%
20	Sheath – Eastman 14285 Core – Basell PDC-1274	5-30%
21	Sheath – Biomer L9000 Core – Basell PDC-1274	5-30%
22	Sheath – Basell PH - 835 Core – Basell PDC-1274	5-30%

Many examples have been shown and given here to demonstrate the breadth of fibers that can be produced to illustrate the invention. The benefit of the hollow fibers of the present invention is demonstrated using Graph 1. Graph 1 shows a plot of Opacity vs Basis Weight for Comparative Example 1 and Example 1.



Graph 1

Graph 1 shows that for the same resin, Basell PH-835, that hollow fibers have better opacity at equivalent basis weight than solid fibers. Another way of interpreting the Graph 1 is to say that the basis weight of the hollow fabric can be reduced from 58gsm to 44gsm and maintain the same level of opacity.

Continuous Fiber Examples

The Examples below further illustrate the present invention. The crystalline PLA was purchased from Biomer as Biomer L9000. The amorphous PLA was purchased from Birmingham Polymer and has an intrinsic viscosity of 1.09 dL/g with an optical rotation of – 12.7. The poly (3-hydroxybutyrate co-alkanoate), PHA, has a molecular weight of 1,000,00g/mol before compounding. The polyhydroxybutyrate (PHB) was purchased from Goodfellow as BU 396010. The polyvinyl alcohol copolymer (PVOH) was purchased from

Air Products Inc. and is a 2000 series polymer. One polypropylene was purchased from FINA as FINA 3860X. Three polypropylenes were purchased from Basell, Profax PH-835, Profax PDC-1298 and Profax PDC-1274. The polyethylene was purchased from Dow Chemical as Aspun 6811A. Five polyester resins were purchased from Eastman Chemical F61HC, 9663, 12822 as well as two copolyester resins 14285 and 20110.

Comparative Example 23: Fibrous web containing solid fibers.

A polypropylene spunbond fabric was produced using solid fiber made from Basell PH-835. The through-put per hole was 0.65ghm using 2016 hole spinneret. The fibers were attenuated to an average fiber diameter of 14µm. These fibers were thermally bonded together using heat and pressure. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
25.9±1.3	26.4±2.8
24.2±1.7	23.8±2.5
17.6±0.4	18.5±1.7

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen. The data presented here is the average of three specimens for each material.

Comparative Example 24: Fibrous web containing solid fibers.

A polypropylene spunbond fabric was produced using solid fiber made from Basell PH-835. The through-put per holes was 0.65ghm using 2016 hole spinneret. The fiber were attenuated to an average fiber diameter of 16µm. These fibers were thermally bonded together using heat and pressure. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
21.1±1.1	18.5±1.7
25.9±1.3	23.8±2.8

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen. The data presented here is the average of three specimens for each material.

Comparative Example 25: Fibrous web containing solid fibers.

A polypropylene spunbond fabric was produced using solid fiber made from FINA 3860X. The through-put per holes was 0.40ghm using 2016 hole spinneret. The fibers were attenuated to an average fiber diameter of 13μm. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
20.8±1.3	21.7±4.7
18.3±1.7	18.8±2.3
16.7±0.4	16.4±4.2

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen. The data presented here is the average of three specimens for each material.

Example 23: Fibrous web containing hollow fibers.

A polypropylene spunbond fabric was produced using hollow fibers made from Basell PH-835. The through-put per holes was 0.40ghm using 1008 hole spinneret. The fibers were attenuated to an average fiber diameter of 17μm. These fibers have an average void volume of 20%. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
18.7±1.2	23.7±1.8
16.3±0.8	20.0±2.0

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen. The data presented here is the average of three specimens for each material.

Example 24: Fibrous web containing hollow fibers.

A polypropylene spunbond fabric was produced using hollow fibers made from Basell PH-835. The through-put per holes was 0.40ghm using 1008 hole spinneret. The fibers were attenuated to an average fiber diameter of 19µm. These fibers have an average void volume of 20%. The following nonwoven fabrics were produced, along with the opacity of the nonwoven measured on the samples in which the basis weight was determined.

Basis Weight (gsm)	**Opacity (%)**
22.2±1.2	26.9±1.8
18.7±0.8	23.5±2.0
16.3±1.2	20.0±1.8
13.9±0.8	17.2±2.0

The opacity measurements are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen. The data presented here is the average of three specimens for each material.

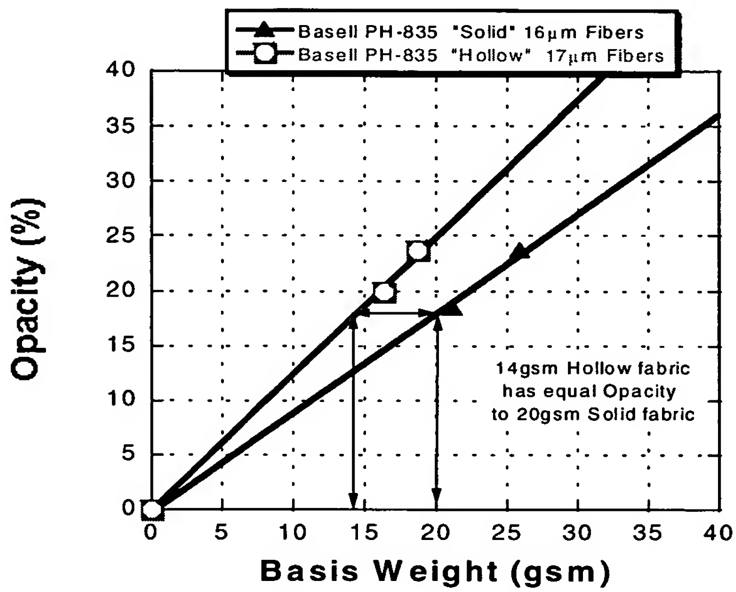
Example 25 - 44: The following table provides examples of continuous fibers and fabrics composed of various polymers. Examples 25-33 illustrate single component fibers and Examples 34-44 illustrate bicomponent fibers. The bicomponent fibers typically have a sheath to core ratio of from about 20:80 to about 80:20. The fibers are produced either a direct spin process or spin and draw process. The table also provides the void volume of the hollow region. The void volumes ranges can be made depending on the mass through-put per hole and melt temperature. As the mass through-put increases and as the melt temperature decreases, the void volume generally increases.

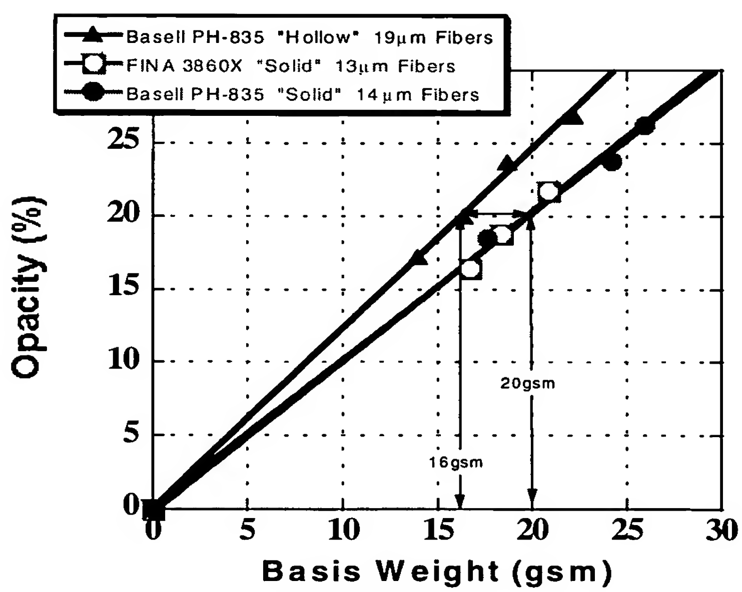
Example Number	Polymer	Void volume
25	PLA - Biomer L9000	5-25%
26	Basell PDC-1274	5-30%

27	Basell PDC-1298	5-40%
28	Dow Aspun 6811A	5-20%
29	Eastman F61HC	5-20%
30	Eastman 9663	5-35%
31	Eastman 12822	5-40%
32	Eastman 14285	5-35%
33	Eastman 20110	5-25%
34	Sheath – Dow Aspun 6811A Core - Basell PH-835	5-25%
35	Sheath -- Dow Aspun 6811A Core – Basell PDC-1274	5-35%
36	Sheath – Dow Aspun 6811A Core – Eastman F61HC	5-25%
37	Sheath – Basell PH-835 Core -- Eastman F61HC	5-25%
38	Sheath – Eastman 20110 Core – Eastman F61HC	5-25%
39	Sheath – Dow Aspun 6811A Core – Eastman 9663	5-25%
40	Sheath – Eastman 14285 Core – Eastman F61HC	5-25%
41	Sheath – Eastman 14285 Core – Eastman 9663	5-30%
42	Sheath – Eastman 14285 Core – Basell PDC-1274	5-30%
43	Sheath – Biomer L9000 Core – Basell PDC-1274	5-30%
44	Sheath – Basell PH - 835 Core – Basell PDC-1274	5-30%

Many examples have been shown and given here to demonstrate the breadth of fibers that can be produced to illustrate the invention. The benefit of the invention can be shown using two graphs. Graph 2 shows a plot of Opacity vs Basis Weight for Comparative

Example 24 and Example 23. One additional data point has been added for each, the requirement that the opacity at zero basis weight is zero. The data in Graph 3 shows a composite plot of Comparative Example 23, Comparative Example 25 and Example 24.





Graph 3

Graph 2 shows that for the same resin, Basell PH-835, that slightly larger diameter hollow fibers have better opacity at equivalent basis weight than solid fibers. Another way of interpreting the Graph 2 shows that the basis weight of the hollow fabric can be reduced from 20gsm to 14gsm and maintain the same level of opacity.

Graph 3 illustrates the full effect of the invention. The much smaller solid fiber produced with FINA 3860X and Basell PH-835 do not match the opacity of a nonwoven produced with larger diameter hollow fibers made with Basell PH-835. This graph shows that the basis weight of the hollow fiber fabric can be reduced from 20gsm to 16gsm and match the much smaller diameter fabric.

The disclosures of all patents, patent applications (and any patents which issue thereon, as well as any corresponding published foreign patent applications), and publications mentioned throughout this description are hereby incorporated by reference herein. It is expressly not admitted, however, that any of the documents incorporated by reference herein teach or disclose the present invention.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is intended to cover in the appended claims all such changes and modifications that are within the scope of the invention.